



## **Smaller, Lower-Power Fast-Neutron Scintillation Detectors**

**There are numerous potential applications in scientific and safety-oriented monitoring of fast neutrons.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Scintillation-based fast-neutron detectors that are smaller and less power-hungry than mainstream scintillation-based fast-neutron detectors are undergoing development. There are numerous applications for such detectors in monitoring fast-neutron fluxes from nuclear reactors, nuclear materials, and natural sources, both on Earth and in outer space. A particularly important terrestrial application for small, low-power, portable fast-neutron detectors lies in the requirement to scan for nuclear materials in cargo and baggage arriving at international transportation facilities.

In the conventional method of detecting fast neutrons (by which is meant neutrons having kinetic energies greater than about 10 keV), the neutrons are first decelerated, by use of moderator materials (typically, paraffin or polyethylene) to near thermal kinetic energies, in order to exploit the fact that the cross sections for interactions of neutrons with other nuclei are largest at low kinetic energies. To be useful for this purpose, moderators must be several inches (of the order of 10 cm) thick. In addition, one must use gas-filled detector tubes containing electrodes to which high bias voltages are applied. Hence, conventional fast-neutron detectors are inherently bulky and heavy.

Several decades ago, scintillation-based detectors were introduced as smaller alternatives to conventional fast-neutron detectors. A scintillation detector of this type includes a photomultiplier tube that monitors a block of a scintillator material (typically, a crystal or a plastic containing a hydrogen rich scintillation dye). A scintillation pulse occurs when a fast neutron knocks a proton in the scintillation material and some of the kinetic energy of the decelerating proton excites luminescence. Although the use of a block of scintillator material is a step toward miniaturization, a photomultiplier tube is still a bulky, high-power device.

The present development of miniature, low-power scintillation-based fast-neutron detectors exploits recent advances in the fabrication of avalanche photodiodes (APDs). Basically, such a detector includes a plastic scintillator, typically between 300 and 400  $\mu\text{m}$  thick with very thin silver mirror coating on all its faces except the one bonded to an APD (see figure). All photons generated from scintillation are thus internally reflected and eventually directed to the APD. This design affords not only compactness but also tight optical coupling for utilization of a relatively large proportion of the scintillation light. The combination of

this tight coupling and the avalanche-multiplication gain (typically between 750 and 1,000) of the APD is expected to have enough sensitivity to enable monitoring of a fast-neutron flux as small as  $1,000 \text{ cm}^{-2}\text{s}^{-1}$ . Moreover, pulse-height analysis can be expected to provide information on the kinetic energies of incident neutrons. It has been estimated that a complete, fully developed fast-neutron detector of this type, would be characterized by linear dimensions of the order of 10 cm or less, a mass of no more than about 0.5 kg, and a power demand of no more than a few watts.

*This work was done by Jagdish Patel and Brent Blaes of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).*

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## **Rotationally Vibrating Electric-Field Mill**

**The disadvantages of rotary couplings in conventional field mills could be avoided.**

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A proposed instrument for measuring a static electric field would be based partly on a conventional rotating-split-cylinder or rotating-split-sphere electric-field mill. However, the design of the proposed instrument would overcome the difficulty, encountered in conventional rotational field mills, of transferring measurement signals and power via either electrical or fiber-optic rotary couplings that must be

aligned and installed in conjunction with rotary bearings. Instead of being made to rotate in one direction at a steady speed as in a conventional rotational field mill, a split-cylinder or split-sphere electrode assembly in the proposed instrument would be set into rotational vibration like that of a metronome. The rotational vibration, synchronized with appropriate rapid electronic switching of electrical connections

between electric-current-measuring circuitry and the split-cylinder or split-sphere electrodes, would result in an electrical measurement effect equivalent to that of a conventional rotational field mill.

The figure depicts a version of the proposed instrument, the electrode assembly of which would include a hollow metal hemisphere split into four electrodes. Instead of a conventional rotary